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U.S. PATENT APPLICATION

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Invention: MANUFACTURE OF SHIM WINDINGS

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SPECIFICATION

MANUFACTURE OF SHIM WINDINGS

This invention relates to the manufacture of coils for use in magnetic resonance imaging spectroscopy (MRIS).

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Magnetic resonance imaging and spectroscopy (MRIS) systems generally comprise a plurality of cylindrical concentric coils which are located around a region within which a patient can be located. The coils include an outermost DC coil which is used to provide a strong constant magnetic field, an inner
10 radio frequency (RF) coil arrangement which is arranged concentrically within the DC coil and a gradient coil assembly which is located between the RF coil and the outer DC coil. The gradient coil assembly is arranged to generate a time-varying audio frequency magnetic field which causes the response frequency of the nuclei of the patient to depend upon their positions within the
15 field. The coils which generate the strong constant magnetic field are generally super-conducting coils. The presence of a patient in the magnetic field may distort the main magnetic field making it insufficiently uniform for imaging or spectroscopic measurements. A known way of counter-acting this effect is by providing multi-turn electrical windings known as shim coils and driving DC
20 electrical currents through those windings. A typical high performance MRIS system may contain 8 to 12 shim coils, each of which is arranged to correct an

inhomogeneity with a particular spatial form. The shim coils can also be used to correct intrinsic inhomogeneities of the super-conductive magnet itself.

5 It is common practice to incorporate shim coils within the structure of the actively shielded gradient coil assemblies which are switched rapidly on and off in a precisely timed sequence to generate MR images. The gradient sequence contains a range of frequencies from zero to 10 kHz or more and this is often referred to as "audio frequency".

10 Magnets with different geometries are currently being developed and these include what are known as open magnets with bi-planar gradient and shim assemblies. The present invention is applicable equally to these new geometries.

15 Shim coils can be divided into two classes. The first class is made up of axial shim coils which comprise a series of complete circular turns and which generate axisymmetric field components. The second class is known as transverse shim coils and these include multiple saddle coils which are typically disposed symmetrically on the surface of a cylinder or some other
20 surface. Depending upon the field component to be corrected a transverse shim can typically comprise 2, 4, 6, 8 or 12 saddles connected in series with

successive saddles having alternating signs as shown for example in Figure 2 of the drawings.

A number of methods are known for fabricating shim coils. These include
5 photo-etching and winding using insulated conductor. The present invention is concerned with an improved method for fabricating shim coils which is applicable not only to saddle type arrangements, but also to axial shim coils.

According to the present invention there is provided a method of forming an
10 electrical coil which comprises forming the required coil pattern in a sheet of electrically conductive material by cutting or punching. The pattern may be punched from the sheet using a CNC punch or stamping machine.

Alternatively, the pattern may be cut using a laser or a water jet. The resulting coil may be a shim coil for use in a MRIS apparatus.

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The invention will be described now by way of example only with particular reference to the accompanying drawings.

In the drawings:

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Figure 1 is a schematic view of a shim saddle coil formed by the method in

accordance with the present invention.

Figure 2 illustrates how shim saddle coils are arranged in a MRIS apparatus.

5 Figure 3 illustrates how an axial shim coil can be made, and

Figure 4 illustrates the formation of an anti-symmetric shim coil.

A method of forming a shim coil in accordance with one embodiment of the
10 present invention comprises the following steps. A sheet of solid conductor is
partially cut to form the conductor pattern shown generally in Figure 1 of the
drawings. This cutting is carried out in such a way that bridges or narrow
joins are left periodically between the conductive elements (10) for support.
The cutting process can be carried out by a variety of techniques which include
15 punching, water-jet cutting, or laser cutting. In the case of punching, the
operation can be carried out using a CNC machine.

The next step in the process is to stick the partially cut pattern onto an
insulating backing material. After this step, the bridges or joining portions are
20 cut away in a second cutting operation. Then a further backing layer is added
in order to insulate the holes which are formed during the cutting operation

which removes the bridges. Finally the pattern is rolled where necessary prior to assembly and connection.

In order to form an axial shim coil a series of discontinuous arcs can be punched in a sheet of conductive material (Figure 3). The discontinuous arcs can include the bridges referred to above with reference to Figure 1. The sheet is then rolled so that opposite ends are adjacent and continuous arcs formed. The opposite ends can be folded about fold lines (12) so that they are juxtaposed in a radial direction. The coil is then located in an MRIS apparatus and electrical connections move to the juxtaposed end portions.

Antisymmetric shim coils can also be formed as shown in Figure 4. A saddle coil is punched from a sheet of conductive material the saddle extending over more than a circumference. This gives an overlap area (14) where axial circuits are cancelled.

In comparison to coils which are hand wound from insulated strips, the method described above has the following advantages:

1. Repeatability
2. Accuracy
3. Correspondence with theoretical design - no rounding of the corners of

a saddle during winding.

4. Reduced labour and skill.
5. Improved structural adhesion compared to insulated conductor.
6. Comparable mean current density when all forms of insulation are taken
5 into account.

In comparison to the prior art technique of photo-etching of coils the above described method has the following advantages:

1. Reduced cost
- 10 2. It is readily scalable to large currents typically of 1 to 10amps.
3. Increased mean current density when all forms of insulation are taken
into account.